N87-17156

ANALYSIS OF MULTIPLE INCIDENCE ANGLE SIR-B DATA FOR DETERMINING FOREST STAND CHARACTERISTICS

R. M. Hoffer, D. F. Lozano-Garcia, D. D. Gillespie, and P. W. Mueller
Department of Forestry and Natural Resources, Purdue University
West Lafayette, Indiana

M. J. Ruzek
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California

I. INTRODUCTION

For the first time in the U. S. space program, digital synthetic aperture radar (SAR) data were obtained from different incidence angles during Space Shuttle Mission 41-G. Shuttle Imaging Radar-B (SIR-B) data were obtained at incidence angles of 58°, 45°, and 28°, on October 9, 10, and 11, 1984, respectively, for a predominantly forested study area in northern Florida. Cloud-free Landsat Thematic Mapper (T.M.) data were obtained over the same area on October 12. The SIR-B data were processed and then digitally registered to the Landsat T.M. data by scientists at the Jet Propulsion Laboratory. This is the only known digitally registered SIR-B and T.M. data set for which the data were obtained nearly simultaneously.

II. OBJECTIVES

1. Determine the potential for utilizing L-band, HH-polarized Shuttle Imaging Radar (SIR-B) data, obtained at incidence angles of 58°, 45°, and 28° to:
   - discriminate and identify forest and other cover types;
   - define differences in density, volume, and biomass in commercial stands of southern yellow pine.

2. Define effective methodologies to quantitatively process and analyze synthetic aperture radar data.

3. Assess changes in forest cover between 1978 and 1984 through the utilization of digitally registered Seasat and SIR-B data.

III. CHARACTERISTICS OF THE TEST SITE

The test site is an area of approximately 1000 sq. km. in northern Florida, approximately 65 km west of Jacksonville. The area has relatively flat terrain and sandy soils. Most of the area is forested, primarily with plantations of slash pine (*Pinus elliottii*). In addition, there are numerous cypress and creek swamps throughout the area which are predominantly pondcypress (*Taxodium distichum* var *nutans*), tupelo (*Nyssa* spp.), and scattered slash pine (*P. elliottii*).

Cover type maps and detailed forest stand inventory data were provided by the U.S.D.A. Forest Service and the three forest products companies operating in the area (Champion International, Owens-Illinois, and Southern Resin). Additionally, at the time of the SIR-B mission, various types of quantitative and qualitative data were obtained, including vegetation and soil moisture samples, temperature and relative humidity measurements, ground and aerial photographs, and stand descriptions.

IV. DATA ANALYSIS AND RESULTS

A data base of more than 1500 forest stands has been developed, although this entire data set could not be used in some of the analyses due to differences in the type and detail of data obtained by each forest product company and the Forest Service. Therefore, statistical analyses were conducted individually on the data base from each company. Significant correlations (0.99 confidence level) were found between many of the forest stand parameters, such as cords/acre and age, trees/acre and age, cords/acre and site index, basal area/acre and cords/acre, and height and age.

Seventy-one stands of slash pine of known characteristics were located in the SIR-B data set, and the relationships between radar backscatter and various stand parameters were determined. Mean radar return was found to be statistically correlated (at the 0.99 confidence level) with age and also with cords/acre for all three SIR-B incidence angle data sets (Table 1). Figure 1 illustrates the relationship between the 58° SIR-B backscatter and age of the forest stands.

Total above-ground wood biomass in tons/acre was calculated for the Owens-Illinois data using a model for slash pine based on D.B.H. (diameter at breast height) and tree height. As indicated in Table 1, statistically significant correlations were found between biomass (in tons/acre) and the 45° and also the 28° incidence angle SIR-B data ($r = 0.60^{**}$ and $r = 0.51^{*}$, respectively), even though this sample contained only a small number of stands.

Analysis of this 58°, 45°, and 28° multiple incidence-angle data set has shown that the incidence angle significantly influences the capability to separate forest cover types. In the 28° incidence angle data set, deciduous swamplands have relatively high radar backscatter while pine planations have only a moderate backscatter, but on the 58° incidence angle data set there are no definable differences, either qualitatively or quantitatively, between these major forest cover types. The very high return observed for the dense cypress and the cypress-tupelo swampland areas on the 28°, and to a lesser degree the 45° data, is believed to be due to the specular reflectance of the radar signal from the standing water in the swamp in combination with the tree trunks, thereby creating a complex corner-reflector effect. The importance of incidence angle on the SIR-B data is dramatically shown in Figure 2.

To determine the most effective procedure for filtering SIR-B data, three different types of low-pass filters (square mean, square median, and separable recursive median) of varying window widths were applied to the data. A separable recursive median filter with a window size of 1 X 5 pixels provided the optimum reduction of speckle effects, based on qualitative evaluations. This filter also enabled somewhat higher computer classification performances to be obtained, as compared to the results using the data generated by the other filters.

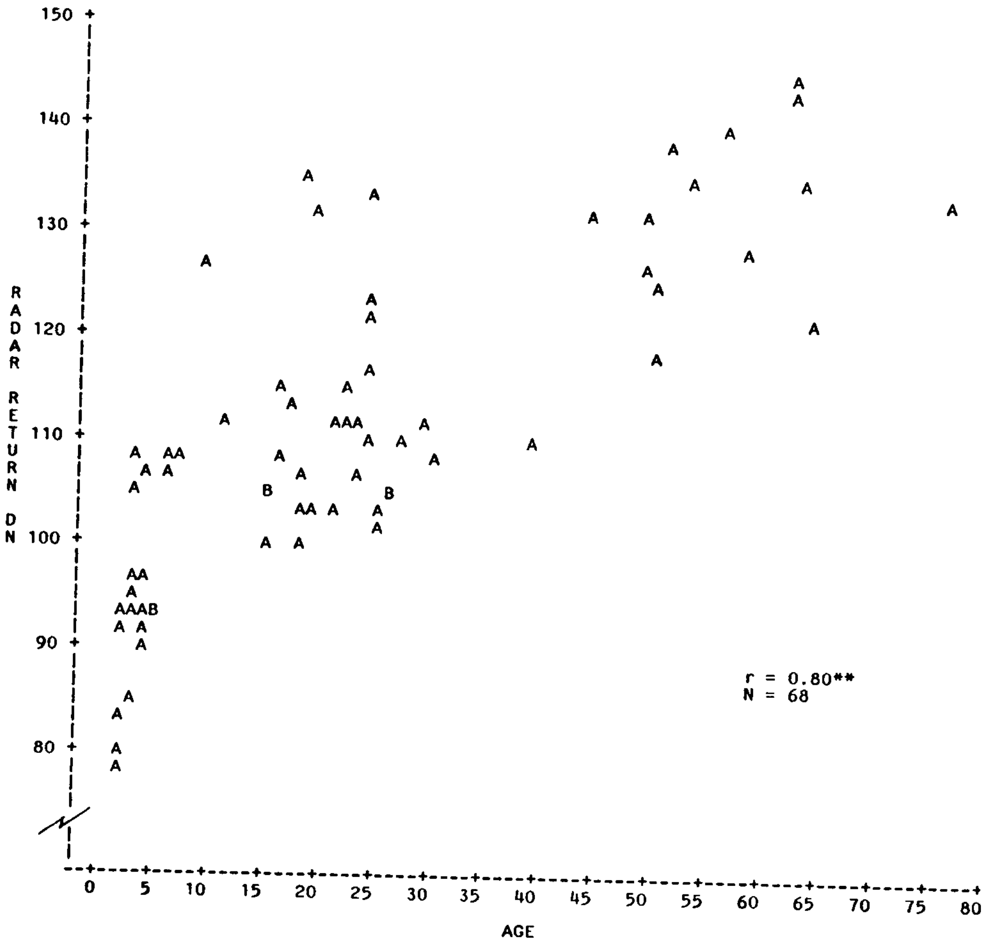

Figure 1. Plot of SIR-B radar backscatter versus age of slash pine. (N = 68 stands; r = 0.80**).

Table 1. Correlation coefficients indicating the relationship between various stand parameters and mean radar return for the stand. A low pass Separable Recursive Median Filter having a 1x5 pixel window has been applied to each of the SIR-B data sets.

Stand parameter	No. stands	SIR-B data set		
		28°	45°	58°
Age	71	0.73**	0.69**	0.81**
Cords/acre	52	0.58**	0.67**	0.52**
Trees/acre	52	0.21	0.32	0.34
Biomass (tons/acre)	17	0.51*	0.60**	0.41

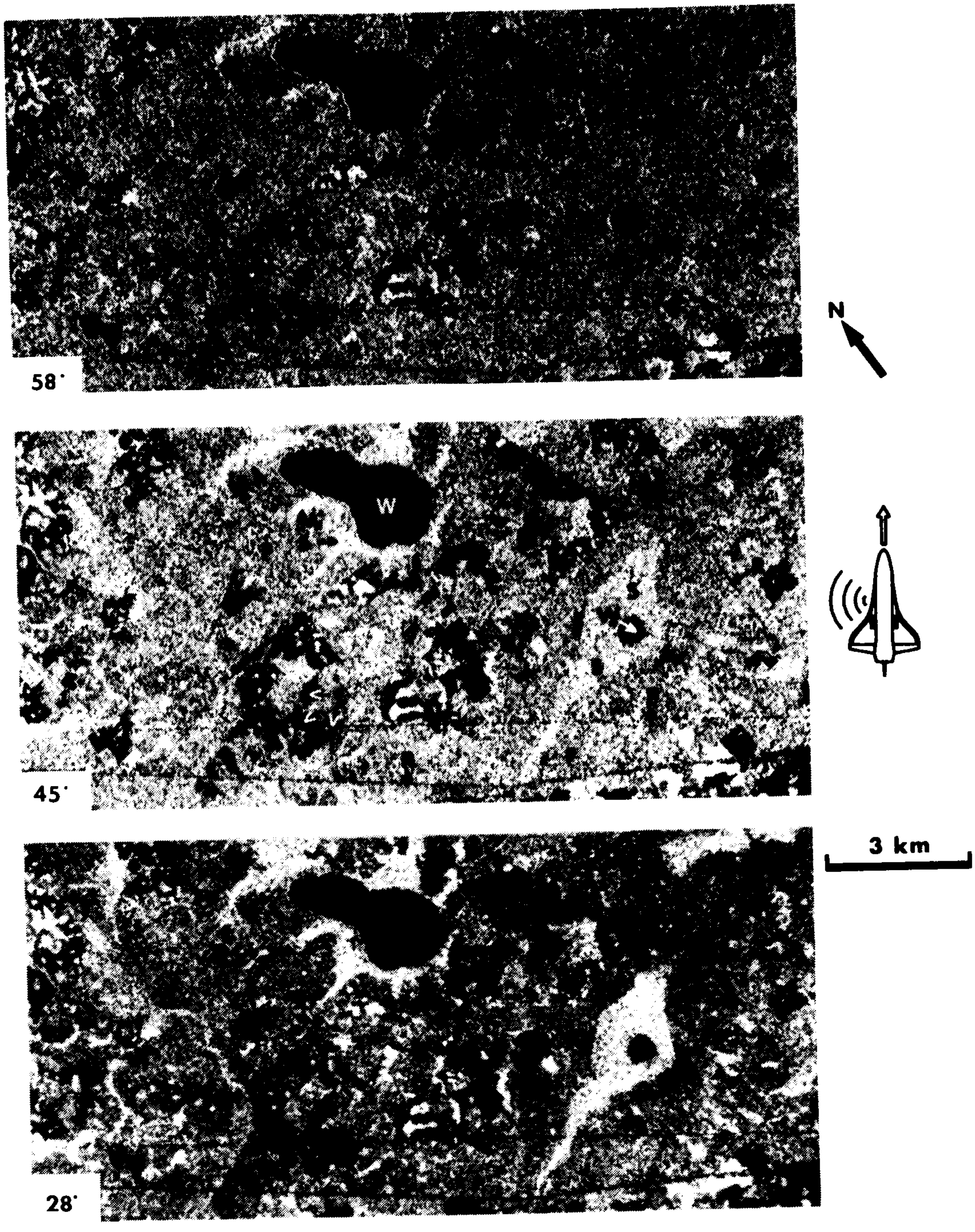

Figure 2. Multiple incidence-angle SIR-B data of the Florida test site. The light-toned areas of deciduous swampland forest are very distinct on the 28° image (bottom), but cannot be differentiated from the surrounding slash pine on the 58° image (top). The center image was obtained at an incidence angle of 45°. W = Water; F = Slash Pine Forest; S = Deciduous Swampland; C = Clearcut; R = Road; and P = Powerline.

Computer classifications were obtained for both the multiple incidence angle SIR-B data and the Landsat T.M. data, using a Gaussian Maximum Likelihood (GML) per-point and also a contextual (SECHO) algorithm. The results were evaluated using 122 test fields containing a total of 8,648 pixels. As shown in Table 2, slash pine forest, deciduous swampland, and other (soil, pasture, water) classes could be classified with reasonably good accuracy using only the multiple incidence angle SIR-B data. Classifications involving old slash pine (>40 yrs.), medium slash pine (6-40 yrs.), young slash pine (<6 years), clearcut, soil, pasture, water, and deciduous swampland produced less accurate results (as would be expected). The overall classification accuracy based on these detailed classes was 70.7% for the per-point GML algorithm and 73.8% for the contextual SECHO algorithm. The Landsat TM multispectral scanner data resulted in higher classification performances for both the generalized and detailed classifications than could be obtained using only the three incidence angles of L-band HH polarized SIR-B data.

Analysis of the digitally registered 1978 Seasat data and 1984 28° SIR-B data showed that areas of deforestation and reforestation could be effectively defined. Although additional work is needed to determine the time period between clearcutting and sufficient forest regrowth to preclude such change detection assessment, it would appear that synthetic aperture radar data could be a very effective tool for monitoring the rate of deforestation in tropical regions of the world, especially since such areas are often cloud covered.

In summary, it is very clear that incidence angle controls, to a very large extent, the characteristics of the data and the type of information that can be obtained from L-Band HH-polarized satellite SAR data. Results of work with aircraft data indicate that the additional frequencies and polarizations that will be available on future satellite platforms will make SAR data an important source of forest resource management information.

Table 2. Results of computer classifications of the unfiltered and filtered SIR-B multiple incidence-angle data for the Gaussian Maximum Likelihood per point and the contextual SECHO classification algorithms. These results are based on 122 test areas containing a total of 8,648 pixels.

GML (per-point) classification algorithm

SIR-B data set (type of low pass filter applied)	Cover type			Overall performance
	Slash pine	Deciduous swampland	Other	
Unfiltered	87.6	79.9	71.6	79.7
3 x 3 mean	94.0	90.4	65.2	85.2
3 x 3 median	92.5	89.9	65.4	84.6
1 x 3 sep. recur. med.	92.4	89.2	65.0	84.1
1 x 5 sep. recur. med.	95.5	92.4	63.8	86.2

Contextual SECHO classification algorithm

SIR-B data set (type of low pass filter applied)	Cover type			Overall performance
	Slash pine	Deciduous swampland	Other	
Unfiltered	94.2	92.8	70.4	87.3
3 x 3 mean	96.9	92.7	67.3	87.0
3 x 3 median	94.7	93.1	60.8	84.8
1 x 3 sep. recur. med.	96.4	92.8	63.4	85.8
1 x 5 sep. recur. med.	97.6	93.2	68.6	87.8